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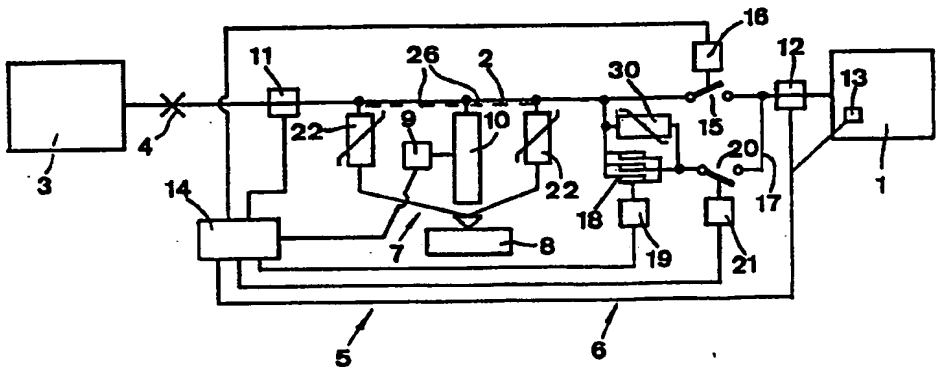

(57) Abstract

This invention is related to a device and a method in an electric power plant for protection of an object (1) against over-currents from a network (3) or another equipment included in the high voltage plant, the device comprising a switching device (4) in a line (2) between the object and the network/equipment. The line (2) between the object and the network/equipment is connected to an arrangement (5) reducing over-currents towards the object (1), said arrangement (5) being actuatable for over-current reduction with the assistance of an over-current condition detecting arrangement (11-13) within a time period substantially less than the break-time of the switching device (4). The over-current reducing arrangement (5) comprises a switch means (10) with an electrode gap, which may be imparted electrical conductivity for over-current diversion.

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A device and a method for protecting an object against fault-related over-currents

FIELD OF THE INVENTION AND PRIOR ART

This invention is related to a device in an electric power plant for protection of an electric object from fault-related over-currents. In addition, the invention includes a method for protecting the object from over-currents.

The electric object in question may be of arbitrary nature as long as it is contained in an electric power network and requires protection against fault-related over-currents, i.e. in practice short-circuit current. As an example, it may be mentioned that the object may be formed by an electric apparatus having a magnetic circuit, e.g. a generator, transformer or motor. Also other objects may be in question, e.g. power lines and cables, switch gear equipment etc. The present invention is intended to be applied in connection with medium and high voltage. According to IEC norm, medium voltage refers to 1-72,5 kV whereas high voltage is >72,5 kV. Thus, transmission, sub-transmission and distribution levels are included.

In prior power plants of this nature one has resorted to, for protection of the object in question, a conventional circuit-breaker (switching device) of such a design that it provides galvanic separation on breaking. Since this circuit breaker must be designed to be able to break very high currents and voltages, it will obtain a comparatively

bulky design with large inertia, which reflects itself in a comparatively long break-time. It is pointed out that the over-current primarily intended is the short-circuit current occurring in connection with the protected object, for instance as a consequence of faults in the electric insulation system of the protected object. Such faults means that the fault current (short-circuit current) of the external network/equipment will tend to flow through the arc. The result may be a very large breakdown. It may be mentioned that for the Swedish power network, the dimensioning short-circuit current/fault-current is 63 kA. In reality, the short-circuit current may amount to 40-50 kA.

A problem with said circuit-breaker is the long-break time thereof. The dimensioning break-time (IEC-norm) for completely accomplished breaking is 150 milliseconds (ms). It is associated to difficulties to reduce this break-time to less than 50-130 ms depending upon the actual case. The consequence thereof is that when there is a fault in the protected object, a very high current will flow through the same during the entire time required for actuating the circuit-breaker to break. During this time the full fault current of the external power network involves a considerable load on the protected object. In order to avoid damage and complete breakdown with respect to the protected object, one has, according to the prior art, constructed the object so that it manages, without appreciable damage, to be subjected to the short-circuit current/fault current during the break-time of the circuit breaker. It is pointed out that a short-circuit current (fault current) in the protected object may be composed of the own contribution of the object to the fault current and the current addition emanating from the network/equipment. The own contribution of the object to the fault current is not influenced by the functioning of the circuit-breaker but the

contribution to the fault current from the network/equipment depends upon the operation of the circuit breaker. The requirement for constructing the protected object so that it may withstand a high short-circuit current/fault current during a considerable time period means substantial disadvantages in the form of more expensive design and reduced performance.

OBJECT OF THE INVENTION

The object of the present invention is to devise ways to design the device and the method so as to achieve better protection for the object and, accordingly, a reduced load on the same, a fact which means that the object itself does not have to be designed to withstand a maximum of short-circuit currents/fault currents during relatively long time periods.

SUMMARY OF THE INVENTION

According to the invention, the object indicated above is achieved in that an over-current reducing arrangement, which is actuatable for over-current reduction with assistance of an over-current conditions detecting arrangement, is connected to the electric power plant for protection of the object, that the over-current reducing arrangement comprises an over-current diverter for diverting over-currents to earth or otherwise another unit having a low potential and that the over-current diverter comprises a switch means, which normally is electric substantially isolating, and means for causing or at least initiating the electrode gap or at least a part thereof to assume electrical conductivity in and for diverting over-currents via the electrode gap.

Thus, the invention is based upon the principle to utilise a rapidly operating switch means, which without effecting any real breaking of the over-current, nevertheless reduces the same to such an extent that the object under protection will be subjected to substantially reduced strains and accordingly a smaller amount of damages. The reduced over-current/fault-current means, accordingly, that the total energy injection into the protected object will be substantially smaller than in absence of the switch means according to the invention.

The solution according to the invention based upon a switch means according to claim 1 implies a particularly advantageous fulfilling of demands which may be set up in order to achieve a satisfactory protection function. Thus, a very rapid trigging may be achieved by the switch means so that originated fault-related over-currents with a very small delay in time will be diverted via the switch means as soon as the electrode gap has adapted an electrical conductive condition. By means of the arrangement of the switch means, said switch means may easily be dimensioned to be able to conduct very large currents. It is in order to obtain a satisfactory protection function namely desirable that the current conducting channel, which is established through the switch means is to be very low-resistant. This means the largest possible strain-relieving of the object, which is to be protected from fault-currents. Besides, a switch means according to claim 1 may with a small effort be caused to function with a particularly high trigging safety. The trigging may in order to as soon as possible divert originated fault-currents therefore not fail in a critical situation. The switch means according to the invention gives on the other hand rise to the possibility to be dimensioned in order to achieve a very high electric strength in a non-trigged condition. The probability for a spontaneous breakthrough is thus to be minimum. The means for causing or at

least initiating the electrical gap to assume electrical conductivity are according to the invention preferred to be arranged to supply trigging energy to the electrode gap in the form of radiative energy. It is especially preferred to thereby use at least one laser for trigging.

Further advantages and features of the invention, particularly with respect to the method according to the invention, appears from the following description and claims.

BRIEF DESCRIPTION OF THE DRAWINGS

With reference to the enclosed drawings, a more specific description of an embodiment example of the invention follows hereinafter.

In the drawings:

Fig 1 is a purely diagrammatical view illustrating the basic aspects behind the solution according to the invention,

Figs 2-2d are diagrams illustrating in a diagrammatical form and in a comparative way fault current developments and the energy development with and without the protection device according to the invention;

Fig 3 is a diagrammatical view illustrating a conceivable design of a device according to the invention;

Fig 4 is a diagrammatical, detailed view illustrating a possible design of the over-current reducing arrangement

Figs 5-7 are views similar to Fig 4 of different variants,

Fig 8 is a diagram, which to the left illustrates different circumstances regarding the strength of the electric field between the electrodes in the switch means in the over-current reducing arrangement and to the right the probability for a spontaneous breakdown as a function of field strength, and

Fig 9 is a diagrammatical view illustrating the device according to the invention, which is applied in an electric power plant comprising a generator, a transformer and a power network connected thereto.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

An electric power plant comprising a protected object 1 is shown in Fig 1. As is described thereunder, this object could for instance consist of a generator. This object is connected, via a line 2, to an external distribution network 3. Instead of such a network, the unit denoted 3 could be formed by some other equipment contained in the power plant. The power plant involved is conceived to be of such a nature that it is the object 1 itself which primarily is intended to be protected against fault currents from the network/equipment 3 when there occurs a fault in the object 1 giving rise to a fault current from the network/equipment 3 towards the object 1 so that the fault current will flow through the object. Said fault may consist in a short-circuit having been formed in the object 1. A short-circuit is a conduction path, which is not intended, between two or more points. The short-circuit may for instance consist of an arc. This short-circuit and the

resulting violent current flow may involve considerable damages and even a total break-down of the object 1.

It is already pointed out that with at least some types of protected electrical objects 1, short-circuit currents/fault currents harmful to the object in question may flow from the protected object towards the network/equipment 3. Within the scope of the invention, it is intended to be used for protection purposes not only for protection of the object from externally emanating fault currents flowing towards the object but also from internal fault currents in the object flowing in the opposite direction. This will be discussed in more detail in the following.

In the following, the designation 3 will, to simplify the description, always be mentioned as consisting of an external power network. However, it should be kept in mind that some other equipment may be involved instead of such a network, as long as said equipment causes violent current flows through the object 1 when there is a fault.

A conventional circuit breaker 4 is arranged in the line 2 between the object 1 and the network 3. This circuit breaker comprises at least one own sensor for sensing circumstances indicative of the fact that there is an overcurrent flowing in the line 2. Such circumstances may be currents/voltages but also other indicating that a fault is at hand. For instance, the sensor may be an arc sensor or a sensor recording short circuit sound etc. When the sensor indicates that the overcurrent is over a certain level, the circuit breaker 4 is activated for breaking of the connection between the object 1 and the network 3. The circuit breaker 4 must, however, break the total short circuit current/fault current. Thus, the circuit breaker must be designed to fulfil highly placed requirements,

which in practice means that it will operate relatively slowly. In Fig 2a it is illustrated in a current/time-diagram that when a fault, for instance a short circuit in the object 1, occurs at the time t_{fault}, the fault current in the line denoted 2 in Fig 1 rapidly assumes the magnitude i_1. This fault current i_1 is broken by means of the circuit breaker 4 at t_1, which is at least within 150 ms after t_{fault}. Fig 2d illustrates the diagram $i^2 \cdot t$ and, accordingly, the energy developed in the protected object 1 as a consequence of the short circuit therein. The energy injection into the object occurring as a consequence of the short-circuit current is, accordingly, represented by the total area of the outer rectangle in Fig 2d.

It is in this connection pointed out that the fault current in Figs 2a-c and the currents in Fig 2d represent the envelope of the extreme value. Only one polarity has been drawn out in the diagram for the sake of simplicity.

The circuit breaker 4 is of such a design that it establishes galvanic separation by separation of metallic contacts. Accordingly, the circuit breaker 4 comprises, as a rule, required auxiliary equipment for arc extinguishing.

According to the invention the line 2 between the object 1 and the switching device 4 is connected to an arrangement reducing overcurrents towards the apparatus 1 and generally denoted 5. The arrangement is actuatable for overcurrent reduction with the assistance of an overcurrent conditions detecting arrangement within a time period substantially less than the break time of the circuit breaker 4. This arrangement 5 is, accordingly, designed such that it does not have to establish any galvanic separation. Therefore, conditions are created to very rapidly establish a current reduction without having to accomplish any total elimination of the current flowing from the network

3 towards the protected object 1. Fig 2b illustrates in contrast to the case according to Fig 2a that the overcurrent reducing arrangement 5 according to the invention is activated upon occurrence of a short circuit current at the time t_{fault} for overcurrent reduction to the level i_2 at the time t_2. The time interval t_{fault}-t_2 represents, accordingly, the reaction time of the overcurrent reducing arrangement 5. Since the task of the arrangement 5 is not to break but only reduce the fault current, the arrangement may be caused to react extremely rapidly, which will be discussed more closely thereunder. As an example, it may be mentioned that current reduction from the level i_1 to the level i_2 is intended to be accomplished within one or a few ms after unacceptable overcurrent conditions having been detected. It is then aimed at to accomplish the current reduction in a shorter time than 1 ms, and preferably more rapidly than 1 microsecond.

As appears from Fig 1, the device comprises a further breaker generally denoted 6 and arranged in the line 2 between the circuit breaker 4 and the object 1. This further breaker is designed to break a lower voltage and current than the circuit breaker 4 and may, as a consequence thereof, be designed to operate with shorter break times than the circuit breaker. The further breaker 6 is arranged to break not until after the overcurrent from the network 3 towards the object 1 has been reduced by means of the overcurrent reducing arrangement 5 but substantially earlier than the circuit breaker 4. From that stated, it appears that the further breaker 6 should be coupled to the line 2 in such a way that it is the current reduced by means of the overcurrent reducing arrangement 5 which will flow through the further breaker and which, accordingly, is to be broken by means thereof.

Fig 2b illustrates the action of the further breaker 6. This breaker is, more specifically, designed to break at the time t_3, which means that the duration of the current i_2 reduced by means of the overcurrent reducing arrangement 5 is substantially delimited, namely to the time period t_2-t_3. The consequence is that the energy injection into the protected object 1 caused by a fault current from the network 3 is represented by the surfaces marked with oblique lines in Fig 2d. It appears that a drastic reduction of the energy injection is achieved. In this connection it is pointed out that since, according to a specific model, the energy increases with the square of the current, a reduction to one half of the current reduces the energy injection to a fourth. It is illustrated in Fig 2c how the fault current will flow through the arrangement 5.

The dimensioning of the arrangement 5 and the further breaker 6 is conceived to be carried out such that the arrangement 5 reduces the fault current and the voltage to be broken by means of the further breaker 6 to substantially lower levels. A realistic break time as to the further breaker 6 is 1 ms. However, the dimensioning should be made such that the breaker 6 is caused to break not until after the arrangement 5 having reduced the current flowing through the breaker 6 to at least a substantial degree.

It is illustrated in more detail in Fig 3 how the device may be realised. It is then pointed out that the invention is applicable in direct current (also HVDC = High Voltage Direct Current) and alternating-current connections. In the latter case, the line denoted 2 may be considered to form one of the phases in a multiphase alternating-current system. However, it should be kept in mind that the device according to the invention may be realised so that either all phases are subjected to the protection function ac-

cording to the invention in case of a detected fault or that only that phase or those phases where a fault current occurs which are subjected to current reduction.

It appears from Fig 3 that the overcurrent reducing arrangement generally denoted 5 comprises an overcurrent diverter 7 for diverting overcurrents to earth 8 or otherwise another unit having a lower potential than the network 3. Thus, the overcurrent diverter may be considered as forming a current divider which rapidly establishes a short circuit to earth or otherwise a low potential 8 for the purpose of diverting at least a substantial part of the current flowing in the line 2 so that said current does not reach the object 1 to be protected. If there is a serious fault in the object 1, for instance a short circuit, which is of the same magnitude as the short circuit that the overcurrent diverter 7 is capable of establishing, it may be said that generally speaking a reduction to one half of the current flowing to the object 1 from the network 3 is achieved as a consequence of the overcurrent diverter 7 in case the fault is close to the latter. In comparison with Fig 2b, it appears, accordingly, that the current level i_2 illustrated therein and being indicated to amount to approximately half of i_1 may be said to represent the worst occurring case. Under normal conditions, the purpose is that the overcurrent diverter 7 should be able to establish a short circuit having a better conductivity than the one corresponding to the short circuit fault in the object 1 to be protected so that accordingly a main part of the fault current is diverted to earth or otherwise a lower potential via the overcurrent diverter 7. It appears from this that, accordingly, in a normal fault case, the energy injection into the object 1 in case of a fault becomes substantially smaller than that which is indicated in Fig 2d as a consequence of lower current level i_2 as well as shorter time span t_2-t_3.

It has been pointed out that the notation 8 not only includes earth but another unit with a lower potential than the network/equipment 3. It is thereby to be noted that the unit 8 possibly could be formed by another power network or another in the current electric power plant included equipment with a lower level of voltage than the one which is effective for the network/equipment 3, to which the object 1, which is to be protected, is connected.

The over-current diverter 7 comprises switch means coupled between earth 8 or said lower potential and the line 2 between the object 1 and the network 3. This switch means comprises a control member 9 and a switch member 10. This switch member is arranged to be open in a normal state, i.e. insulating in relation to earth. The switch member 10 may however be brought into a conductive state via the control member 9 in a very short time in order to establish current reduction by diversion to earth.

Fig 3 illustrates that an overcurrent conditions detecting arrangement may comprise at least one and preferably several sensors 11-13 suitable for detecting such overcurrent situations requiring activation of the protection function. As also appears from Fig 3, these sensors may include the sensor denoted 13 located in the object 1 or in its vicinity. Furthermore, the detector arrangement comprises a sensor 11 adapted to sense overcurrent conditions in the line 2 upstreams of the connection of the overcurrent reducing arrangement 5 and the line 2. As is also explained in the following, it is suitable that a further sensor 12 is provided to sense the current flowing in the line 2 towards the object 1 to be protected, i.e. the current which has been reduced by means of the overcurrent reducing arrangement 5. In addition, it is pointed out that the sensor 12, as well as possibly the sensor 13, is

capable of sensing the current flowing in the line 2 in a direction away from the object 1, for instance in cases where energy magnetically stored in the object 1 gives rise to a current directed away from the object 1.

It is pointed out that the sensors 11-13 do not necessarily have to be constituted by only current and/or voltage sensing sensors. Within the scope of the invention, the sensors may be of such nature that they generally speaking may sense any conditions indicative of the occurrence of a fault of the nature requiring initiation of a protection function.

In cases where such a fault occurs that the fault current will flow in a direction away from the object 1, the device is designed such that the control unit 14 thereof will control the further breaker 6 to closing, in case it would have been open, and, in addition, the overcurrent reducing arrangement 5 is activated such that the short circuit current may be diverted by means of the same. When, for example, the object 1 is conceived to consist of a transformer, the function on occurrence of a short circuit therein could be such that the short circuit first gives rise to a violent flow of current into the transformer, which is detected and gives rise to activation of the arrangement 5 for the purpose of current diversion. When the current flowing towards the transformer 1 has been reduced in a required degree, the breaker 6 is caused to break, but, controlled by means of the control unit 14, not earlier than leaving time for the energy, in occurring cases, magnetically stored in the transformer 1 to flow away from the transformer 1 and be diverted via the arrangement 5.

Furthermore, the device comprises a control unit generally denoted 14. This is connected to the sensors 11-13, to the

overcurrent reducing arrangement 5 and to the further breaker 6. The operation is such that when the control unit 14 via one or more of the sensors 11-13 receives signals indicating occurrence of unacceptable fault currents towards the object 1, the overcurrent reducing arrangement 5 is immediately controlled to rapidly provide the required current reduction. The control unit 14 may be arranged such that when the sensor 12 has sensed that the current or voltage has been reduced to a sufficient degree, it controls the breaker 6 to obtain operation thereof for breaking when the overcurrent is below a predetermined level. Such a design ensures that the breaker 6 is not caused to break until the current really has been reduced to such a degree that the breaker 6 is not given the task to break such a high current that it is not adequately dimensioned for that purpose. However, the embodiment may alternatively also be such that the breaker 6 is controlled to break a certain predetermined time after the overcurrent reducing arrangement having been controlled to carry out current reduction.

The circuit breaker 4 may comprise a detector arrangement of its own for detection of overcurrent situations or otherwise the circuit breaker may be controlled via the control unit 14 based upon information from the same sensors 11-13 also controlling the operation of the overcurrent reducing arrangement.

It is illustrated in Fig 3 that the further breaker 6 comprises a switch 15 having metallic contacts. This switch 15 is operable between breaking and closing positions by means of an operating member 16, which in turn is controlled by the control unit 14. A shunt line 17 is connected in parallel over this switch 15, said shunt line comprising one or more components 18 intended to avoid arcs on separation of the contacts of the switch 15 by

causing the shunt line 17 to take over the current conduction from the contacts. These components are designed so that they may break or restrict the current. Thus, the purpose is that the components 18 normally should keep the conduction path in the shunt line 17 interrupted but close the shunt line when the switch 15 is to be opened so that accordingly the current is shunted past the switch 15 and in that way arcs do not occur or possibly occurring arcs are efficiently extinguished. The components 18 comprise one or more associated control members 19 connected to the control unit 14 for control purposes. According to one embodiment of the invention, said components 18 are controllable semiconductor components, for instance GTO thyristors, having necessary surge arresters 30.

A disconnector 20 for galvanic separation in the current conduction path created by means of the shunt line 17 to the object 1 to be protected is arranged in series with said one or more components 18. This disconnector 20 is via an operating member 21 controlled by the control unit 14. The disconnector 20 is illustrated in Fig 3 as being placed in the shunt line 17 itself. This is of course not necessary. The disconnector 20 could also be placed in the line 2 as long as it ensures real galvanic separation, by series coupling with said one or more components 18, in the conduction path established by means of said series coupling so that accordingly there is not any possibility for current to flow through the components 18.

The device as it has been described so far operates in the following manner: In absence of a fault, the circuit breaker 4 is closed just like the switch 15 of the further breaker 6. The components 18 in the shunt line 17 are in a non-conducting state. The disconnector 20 is closed. Finally, the switch means 10 of the overcurrent reducing arrangement 5 is open, i.e. it is in a non-conducting state.

In this situation the switch means 10 must, of course, have an adequate electrical strength so that it is not inadvertently brought into a conducting state. Overvoltage conditions occurring in the line 2 as a consequence of atmospheric (lightning stroke) circumstances or coupling measures may, accordingly, not involve the voltage strength of the switch means 10 in its non-conducting state to be exceeded. For this purpose it is suitable to couple at least one surge arrester 22 in parallel with the switch means 10. In the example such surge arresters are illustrated on both sides of the switch means 10. Accordingly, the surge arresters have the purpose to divert such overvoltages which otherwise could involve a risk for inadvertent breakthrough in the switch means 10.

The over-current diverters 22 are illustrated in Fig 3 to be connected to the line 2 itself on either sides of the connection of the switch means 10 to the line. It is in principle desirable that at least one over-voltage diverter has its connection as close as possible upstreams in relation to the switch means 10. The over-current diverters 22 could instead, which is indicated in Fig. 3 with the dotted lines 26 be connected to the branch line forming electric connection between the switch means 10 and the line 2. Such a construction enables integration of the switch means 10 and at least one over-voltage diverter 22 to one single electric apparatus, which apparatus may be brought in electric conducting connection with the line 2 via one single connection.

When an over-current state has been registered by means of some of the sensors 11-13 or the own sensor (it is of course realized that information from the own sensor of the circuit breaker 4 may be used as a basis for control of the over-current reducing arrangement 5 according to the invention) of the circuit breaker 4 and this over-current state is of such magnitude that a serious fault of

the object 1 is expected to be at hand, a breaking operation is initiated as far as the circuit breaker 4 is concerned. In addition, the control unit 14 controls the over-current reducing arrangement 5 to effect such reduction, and this more specifically by bringing, via the control member 9, the switch means 10 into an electrically conducting state. As described before, this may occur very rapidly, i.e. in a fraction of the time required for breaking by means of the circuit breaker 4, for what reason the object 1 to be protected immediately is liberated from the full short-circuit current from the network 3 as a consequence of the switch means 10 diverting at least an essential part, and in practice the main part, of the current to earth or otherwise a lower potential. As soon as the current, which flows towards the object 1 via the further breaker 6, has been reduced in a required degree, which can be established on a pure time basis by a time difference between activation of the switch means 10 and operation of the breaker 6, or by sensing of the current flowing in the line 2 by means of, for instance, the sensor 12, the operating member 16 of the switch 15 is, via the control unit 14, controlled to open the contacts of the switch 15. For extinguishing or avoiding arcs, the components 18, e.g. GTO thyristors or gas switches, are via the control members 19 controlled to establish conductivity of the shunt line 17. When the switch 15 has been opened and, thus, provided galvanic separation, the component 18 is again controlled to bring the shunt line 17 into a non-conducting state. In that way the current from the network 3 towards the object 1 has been efficiently cut off. After having brought the shunt line 17 into a non-conducting state, galvanic separation may, in addition, be effected by means of the disconnector 20 by controlling the operating member 21 thereof from the control unit 14. When all these incidents have occurred, breaking by means of the circuit breaker 4 occurs as a last inci-

dent. It is important to note that the over-current reducing arrangement as well as the further breaker 6 according to a first embodiment can be operated repeatedly. Thus, when it has been established by means of the sensors 11-13 that the circuit breaker 4 has been brought to cut off, the switch means 10 is reset to a non-conducting state and the switch 15 and the disconnector 20 are again closed so that when the circuit breaker 4 next time closes, the protection device is completely operable. According to another embodiment, it is, however, contemplated that the over-current reducing arrangement 5 may require exchange of one or more parts in order to operate again.

It is pointed out that according to an alternative embodiment of the invention, the component or components 18 could be brought into a conducting state as soon as the over-current reducing arrangement 5 has been brought into a closing state and this independently of whether the switch 15 possibly is not opened thereafter. The control of the components 18 could then, as described before, occur via the control unit 14 or, alternatively, by means of a control function involving a slavish following of the closing of the arrangement 5.

Fig 4 illustrates a first embodiment of the over-current reducing arrangement 5 with switch means denoted 10a. The switch means 10a has electrodes 23 and a gap 24 prevailing between these electrodes. The switch means as it has been described so far has means 25a in order to trigg the electrode gap 24 to form an electrical conducting path between the electrodes. A control member 9a is arranged to control the operation of the members 25a via the control unit 14a. The means 25a are in the example arranged for causing or at least initiating the electrode gap to assume electrical conductivity by means of causing the gap or part thereof to form a plasma. It is thereby substantial that the means 25a

are capable of realising a very rapid supply of trigging energy to the electrode gap. It is thereby preferred that the trigging energy is supplied in the form of radiative energy, which in turn is capable of effecting ionising/initiating of plasma in the electrode gap.

The means 25a comprises according to a preferred embodiment of the invention at least one laser, which by means of energy supply to the electrode gap causes ionising/forming of plasma in at least a part of the electrode gap.

Although it would be possible with the aid of one or several lasers or other means 25a to supply energy to the electrode gap 24 in a way that the complete electrode gap will be ionised and brought to the form of a plasma respectively, approximately momentarily in a way that also the complete gap 24 immediately is brought to electrical conductivity, the means 25a are generally intended to be arranged in a way that they manage to effect ionising/forming of plasma in part of the gap 24 at application of the invention.

By connecting the switch means 10a between the line 2 and earth 8 (or another unit with lower potential) as is diagrammatically indicated in Fig 4, i.e. with one of the electrodes 23 connected to the line 2 and the other electrode connected to earth 8, there will be a voltage difference between the electrodes causing an electric field. The electric field in the gap 24 is intended to be utilised in order to convey or cause an electric breakdown between the electrodes as soon as the means 25a have been controlled for trigging, i.e. have given rise to ionising/forming of plasma in part of the electrode gap. The established ionising/forming of plasma will be driven by the electric field to shunt the gap between the electrodes in order to in this way give rise to a low-resistant electrical conductive channel, i.e. an arc between the electrodes 23.

Due to the demand on the switch means 10a to stop very rapid for current diversion, it is thus desirable that the switch means is dimensioned in a way that the strength of the electric field in the gap 24 will be high. It is however on the other hand a desire that the switch means 10a should have a very high electric strength against breakdowns between electrodes in its isolating rest position. The strength of the electric field in the gap 24 should therefore be proportionally low. This will on the other hand reduce the speed, with which the switch means may be caused to establish the current diverting arc between the electrodes. These circumstances are illustrated in Fig. 8 where the electric field strength is indicated with E. The level E_{sp} represent the field strength, at which a spontaneous breakdown originates. The probability P for a spontaneous breakdown as a function of the field strength E is illustrated to the right in Fig 8. In order to achieve an advantageous relation between the desire for a safe trigging of the switch means and on the other hand high electric strength against undesired trigging, it is according to the invention preferred that the switch means is formed in a way that regarding its complete operational environment the electric field in the gap 24 has a field strength which is not more than 70% of the field strength at which a spontaneous breakdown normally takes place, when the gap forms electric isolation. This field strength is denoted with E_1 to the left in Fig 8. This causes a proportionally low probability of a spontaneous breakdown, which is evident to the right in Fig 8.

The strength of the electric field in the electrode gap 24 in its isolating state is suitably not more than 50% (E_2) and preferably not more than 40% (E_3) of the field strength at which a spontaneous breakdown normally takes place. It is to the right in Fig 8 evident that the field strength levels E_2 and E_3 implies that the probability of a spontaneous

breakdown approaches 0. In order to on the other hand achieve an electric field in the electrode gap 24, which promotes forming of an arc at initiation of ionising/forming of plasma in a part of the electrode gap in a relatively rapid way, it is preferred that the strength in the electric field is at least 5% and suitably at least 10% (E_4) of the field strength, at which a spontaneous breakdown normally takes place. It is thus preferred that the field strength is in the interval 10-40% of the field strength, at which a spontaneous breakdown normally takes place. Especially good results have been noted at approximately 20% by means of tests.

The electrode gap 24 is, as may be seen in Fig. 4, comprised in a suitable casing 32. A vacuum as well as a suitable medium in the form of gas or even fluid may for this purpose be present in the gap 24. In the case of a gas/fluid the medium in the gap is intended to be formed in a way that it might be ionised and brought to plasma by trigging. It would in such a case be suitable to initiate ionisation/forming of plasma in the gap 24 at a point somewhere between the electrodes 23. It is however in Fig 4 illustrated the conceived case where there either is a vacuum or a suitable medium in the gap 24. It is then preferred that initiation of closing takes place by way of making the laser 25a, which is illustrated in Fig 4, to focus the omitted radiative energy in an area 28 on one of the electrodes via a suitable optical system 27. This implies that the electrode will operate as an electron and ion emitter for establishing an ionised environment/a plasma in the electrode gap 24 in a way that thus an arc will be formed between the electrodes. One of the electrodes 23 may according to Fig 4 have an opening 29, through which the laser 25a is arranged to emit the radiative energy to the area 28 with support of the optical system 27.

Fig 5 illustrates a variant 10b of the switch means, where instead the system laser 25b/optics 27b focus the radiative energy in a trigging area 28b, which is situated between the electrodes and in a medium between these electrodes. Plasma is accordingly intended to be developed from this area by trigging to a shunt of the electrodes.

The variant 10c of the switch means in Fig 6 differs from the one in Fig 4 in the way that auxiliary electrodes 31 have been arranged between the electrodes 23c in this case, said auxiliary electrodes suitably being annular in a way that the jet emitted by the laser 25c may pass through the auxiliary electrodes 31. These electrodes are intended to operate for smoothing the electric field between the electrodes 23c and may be isolated from each other, i.e. they may be on a floating potential. The auxiliary electrodes result in improved safety against a spontaneous breakthrough, reduced dimensions of the switch means and a reduced sensitivity to the effect of external fields.

Fig 7 illustrates a variant 10d of the switch means with the change that the electrodes 31d are added also here, in similarity to what has been described with the reference to Fig 6.

In order to achieve the above discussed relations according to the field strength conditions between the electrodes 23 in the isolating state of the switch means, the characteristics of the switch means may of course be adapted to the intended use, i.e. the voltage conditions which will arise over the electrodes 23. The constructive steps available regard of course forming of the electrodes, distance between the electrodes, the medium between the electrodes and the presence of possible field effecting components between the electrodes.

Fig 9 illustrates an embodiment where a generator 1b is connected to a power network 3a via a transformer 1a. The objects which are to be protected are therefore represented by the transformer 1a and the generator 1b. The over-current reducing arrangement 5a and the further breaker 6a as well as the ordinary circuit breaker 4a are apparently arranged in resemblance with what is evident from Fig 1 in the case that the object 1 in Fig 1 is conceived to form the object 1a according to Fig 9. It is therefore in this regard referred to the descriptions in connection to Fig 1. The same is true for the protection operation of the over-current reducing arrangement 5b and the further breaker 6c in relation to the generator 1b. The generator 1b should therefore in this case be equivalent to the object 1 in Fig 1 while the transformer 1a should be equivalent to the equipment 3 in Fig 1. The over-current reducing arrangement 5c and the further breaker 6c will therefore in combination with the invention circuit breaker 4b be able to protect the generator 1b against a violent current flow in the direction from the transformer 1a.

Fig 9 also illustrates the further over-current reducing arrangement 5b with the associated further breaker 6b. Apparently, over-current reducing arrangements 5a and 5b will therefore be arranged on either sides of the transformer 1a. It is to be noted that the further breakers 6a and 6b, respectively are positioned in the connections between said over-current reducing arrangements 5a and 5b and the transformer 1a. The further over-current reducing arrangement 5b is intended to protect the transformer 1a from violent current flows towards the transformer from the generator 1b. The circuit breaker 4b will apparently be capable of breaking independent of in which direction between the objects 1a and 1b safety function is desired.

It should be noted that the description presented hereinabove only should be considered as exemplifying for the inventive idea, on which the invention is built. Thus, it is obvious for the men skilled in the art that detailed modifications may be made without leaving the scope of the invention. As an example, it may be mentioned that according to the invention, it is not necessary to use a laser for supply of ionising/plasma forming energy to the gap 24. Also other radiative sources, for example electron guns, or other energy supply solutions may be applied as long as the rapidness and reliability demands according to the invention are fulfilled. It should be observed that the switch means 10 may according to the invention be applied for protection of electric objects against fault-related over-currents also in other operative cases than the ones illustrated in Figs 1, 3 and 9, where the device according to the invention is arranged in order to reduce the negative effects of the proportionately enlarged breaking time of the circuit breaker 4. Thus, the switch means according to the invention does not necessarily need to be operation-related to such a circuit breaker 4. It should finally be observed that the trigging energy to the electrode gap does not necessarily need to be supplied through an opening 29 in one of the electrodes.

Claims

1. A device in an electric power plant for protection of an electric object (1) from fault-related over-currents, characterized in that, an over-current reducing arrangement (5), which is actuatable for over-current reduction with assistance of an over-current conditions detecting arrangement (11-13), is connected to the electric power plant for protection of the object, that the over-current reducing arrangement (5) comprises an over-current diverter (7) for diverting over-currents to earth (8) or otherwise another unit having a low potential and that the over-current diverter (7) comprises a switch means (10), which comprises an electrode gap (24), which normally is electric substantially isolating, and means (25) for causing or at least initiating the electrode gap or at least a part thereof to assume electrical conductivity in and for diverting over-currents via the electrode gap.

2. A device according to claim 1, characterized by said means (25) for causing or at least initiating the electrode gap (24) to assume electrical conductivity being arranged to cause the gap or part thereof to the form of a plasma.

3. A device according to claim 1 or 2, characterized by said means (25) for causing or at least initiating the electrode gap (24) to assume electrical conductivity being arranged to rapidly supply trigging energy to the electrode gap.

4. A device according to claim 3, characterized by said means (25) for causing or at least initiating the electrode gap to assume electrical conductivity being arranged for feeding trigging energy to the electrode gap in the form of radiative energy.

5. A device according to any preceding claim, characterized by said means (25) for causing or at least initiating the electrode gap or part thereof to assume electrical conductivity comprising at least one laser (25).

6. A device according to any preceding claim, characterized in that the switch means (10) is formed in a way that an electric field is present in its isolating condition between its electrodes (23), which field transfers or drives an electric flash-over between the electrodes on causing or initiating the electrode gap to assume electrical conductivity.

7. A device according to claim 6, characterized in that the electric field in the isolating condition of the electrode gap (24) has substantially less field strength than the field strength, at which a spontaneous breakthrough takes place.

8. A device according to claim 6 or 7, characterized in that the electric field in the insulating condition of the electrode gap (24) has a field strength which is not more than 70%, suitably not more than 50% and preferably not more than 40% of the field strength, at which a spontaneous breakthrough takes place.

9. A device according to any of the claims 6-8, characterized in that the electric field in the insulating condition of the electrode gap (24) has a field strength which is at least 5%, suitably at least 10%, of the field strength, at which a spontaneous breakthrough takes place.

10. A device according to claim 4 or 5, characterized in that the means (25a, c) for supplying trigging energy to the electrode gap are arranged in order to apply the radiative energy on at least one of the electrodes (23).

11. A device according to claim 4 or 5, characterized in that the means (25b, d) for supplying trigging energy to the electrode gap are arranged to focus the radiative energy to one point in the gap (24b, d) between the electrodes (23b, d).

12. A device according to any of the claims 4, 5, 10 and 11, characterized in that at least one of the electrodes at the electrode gap has an opening (29), through which the means (25) for supplying trigging energy are arranged in order to direct the radiative energy.

13. A device according to any preceding claim, characterized in that auxiliary electrodes (31, 31d) for equalising the electric field are arranged at the gap (24) between the electrodes.

14. A device according to any preceding claim, characterized in that at least one over-voltage diverter (22) is connected in parallel to the switch means (10).

15. A device according to any preceding claims, whereas the electric object (1) is connected to an electric power network (3) or another equipment included in the electric power plant, the device comprising a switching device (4) in a line (2) between the object and the network/equipment, characterized in that the switch means (10) is connected to the line (2) between the object (1) and the switching device (4), and that the switch means (10) is actuatable for over-current diversion within a time period substantially shorter than the break-time of the switching device (4).

16. A device according to claim 15, characterized in that the switching device (4) is formed by a power breaker.

17. A device according to claim 15 or 16, characterized in that it comprises a further breaker (6) arranged in the line between the switching device (4) and the object, said further breaker being arranged between the switching means (10) and the object (1) and being adapted to break lower voltages and currents than the switching device (4) and therefore capable of performing a shorter break-time than the switching device and that the further breaker is adapted to break when the over-current towards or away from the object (1) has been reduced by means of the switch means (10) but substantially earlier than the switching device.

18. A device according to claim 17, characterized in that it comprises a control unit (14) connected to the detecting arrangement (11-13) and to the further breaker (6) in order to achieve actuation of the further breaker for breaking purposes when the over-current towards or away from the object (1) is indicated, by means of the detecting arrangement, to be under a predetermined level.

19. A device according to any of the claims 17-18, characterized in that the further breaker (6) comprises a switch (15) over which there is coupled a shunt line (17) having one or more components (18) for avoiding arcs of separation of contacts of the switch (15) by causing the shuntline (17) to take over current conduction from the contacts.

20. A device according to claim 19, characterized in that said one or more components (18) in the shunt line (17) are closable into conduction by means of control via the control unit (14).

21. A device according to claim 19 or 20, characterized in that said one or more components (18) are formed by semiconductor components.

22. A device according to any of the claims 19-21, characterized in that said one or more components (18) are provided with at least one surge arrester (30).

23. A device according to any of the claims 19-22, characterized in that a disconnector (20) for galvanic separation is arranged in series with said one or more components (18).

24. A device according to claim 23, characterized in that the disconnector (20) is coupled to the control unit (14) to be controlled thereof for opening after the switch (15) having been controlled to have closed and said one or more components (18) having been placed in a condition for breaking the shunt line (17).

25. A device according to any preceding claim, characterized in that the protected object (1) is formed by an electric apparatus with a magnetic circuit.

26. A device according to claim 25, characterized in that the object is formed by a generator, transformer or motor.

27. A device according to any of the claims 1-26, characterized in that the object is a power line, e.g. a cable.

28. A device according to any preceding claim, characterized in that two switch means (10) are arranged on either sides of the object to protect the same from two sides.

29. A device according to claim 1, characterized in that it comprises a control unit (14) connected to the switch means (10) and to the over-current conditions detecting arrangements (11-13), said control unit (14) being arranged to control the switch means to closing based upon information from the over-current conditions detecting arrangement when required for reasons of protection.

30. A device according to claim 29 and one or more of the claims 18, 20 and 24, characterized in that one and the same control unit (14) is arranged to control, based upon information from the over-current conditions detecting arrangement (11-13), the switch means (10) and the further breaker (6).

31. Use of a device according to any preceding claim for protection of an object against fault-related over-currents.

32. A method in an electric power plant for protection of an electric object (1) from fault-related over-currents, characterized in that over-current diversion is accomplished by means of a switch means (10) when over-current conditions have been detected by means of an arrangement (11-13) for such detection, said switch means (10) being arranged for diversion of over-currents to earth (8) or some other unit with low potential to closing for over-current diversion by means of that an electrode gap (24), which is present in the switch means, is imparted electrical conductivity with the aid of trigging means (25).

33. A method according to claim 32, characterized in that a further breaker (6), which is arranged in a line (2) between a switching device (4) and the object (1) and between the switch means (10) and the object (1), is actuated for breaking after the over-current towards or away from the object (1) having been reduced by means of the switch means (10).

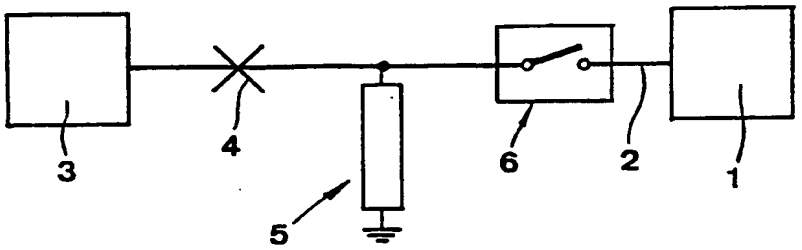

Fig 1

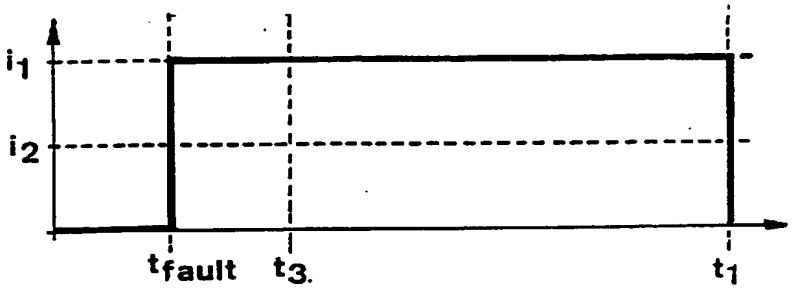

Fig 2a

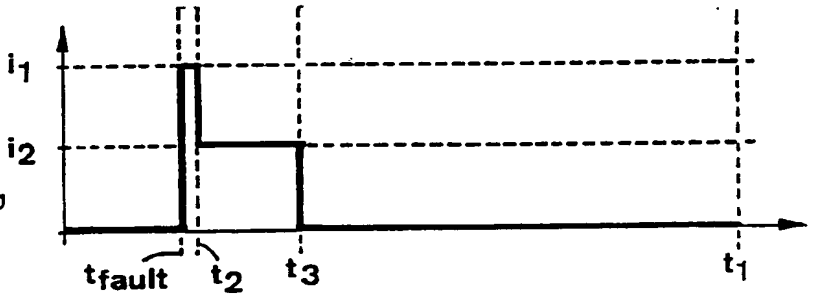

Fig 2b

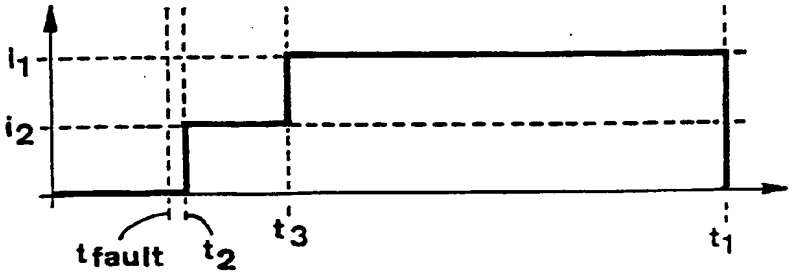

Fig 2c

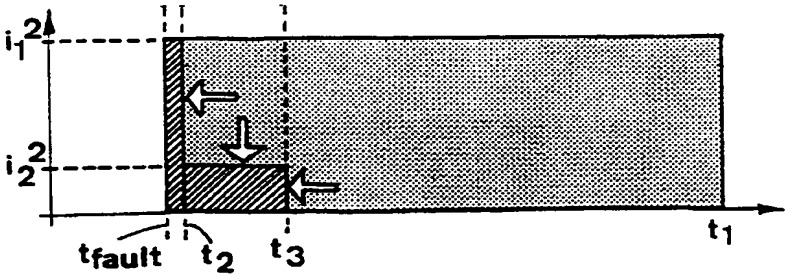

Fig 2d

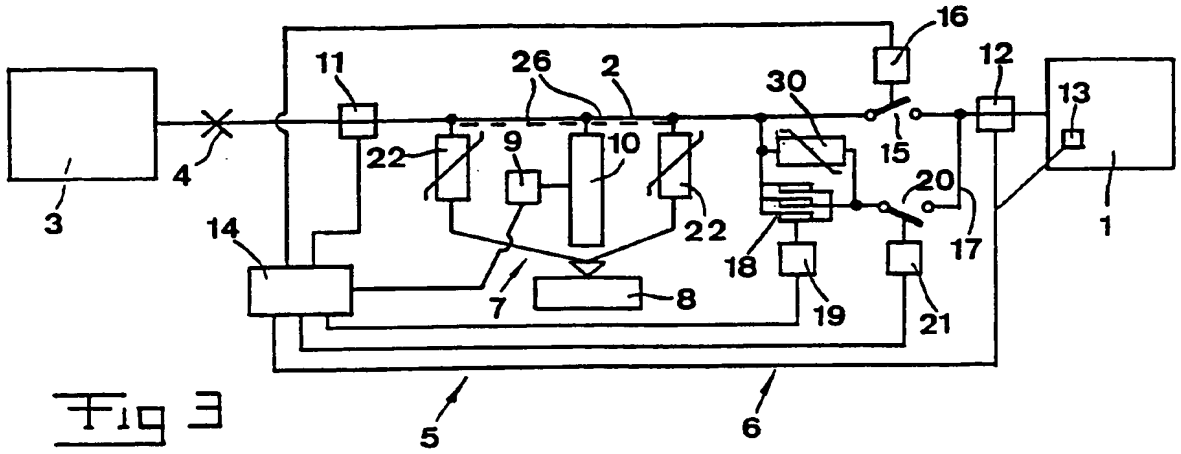
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Fig 3

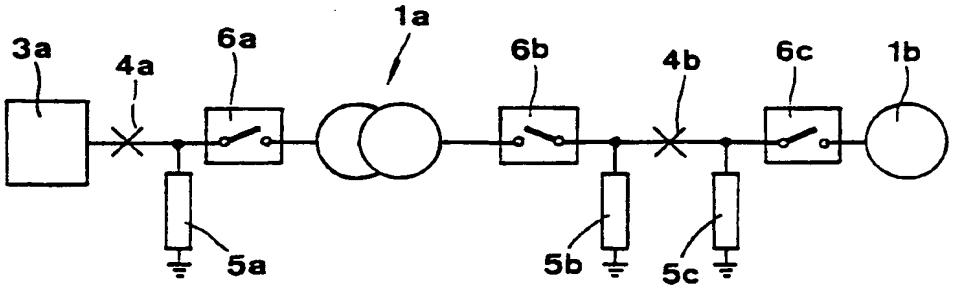
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Fig 9

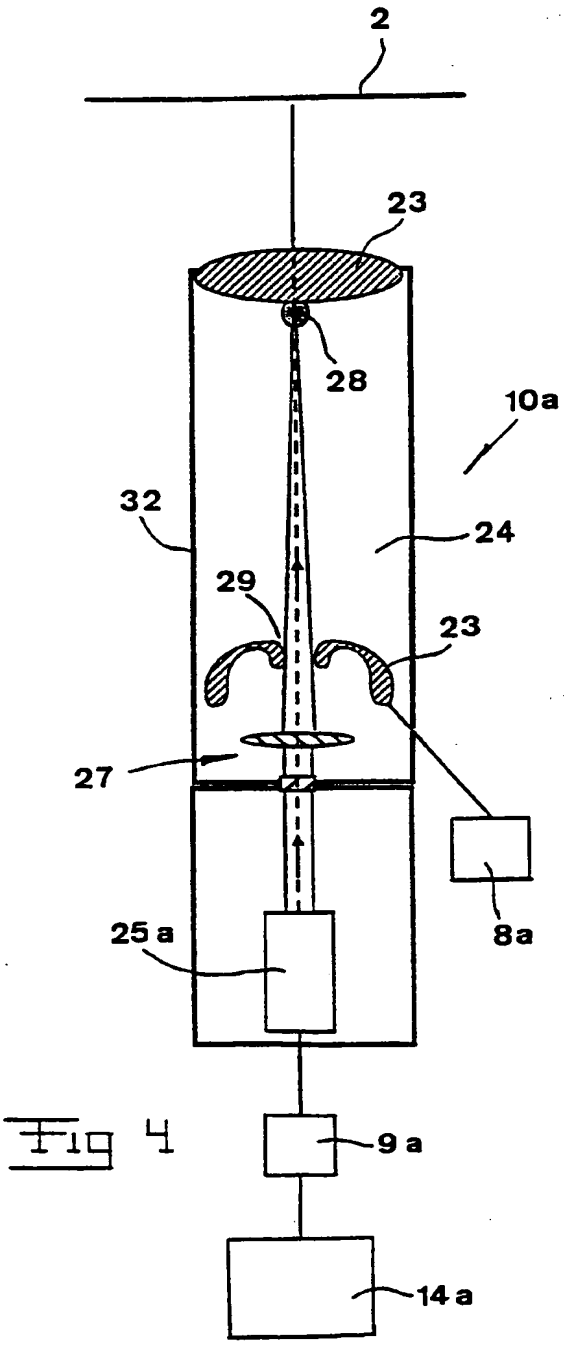

Fig 4

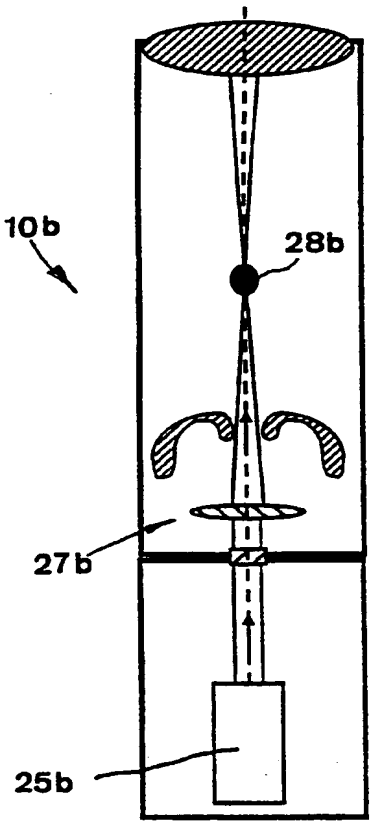

Fig 5

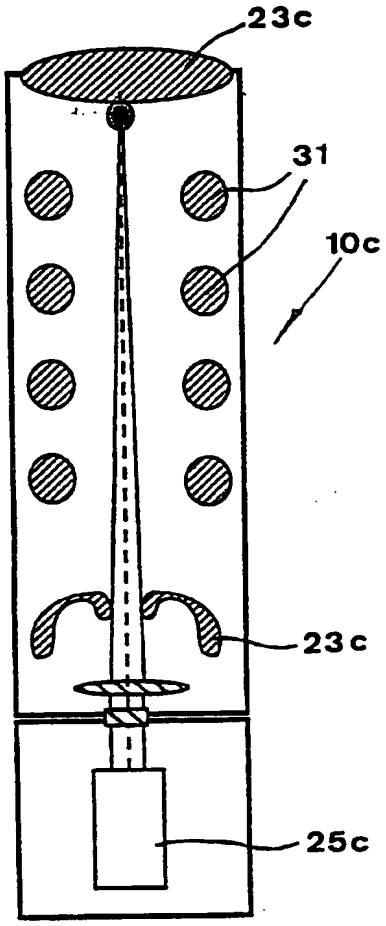

Fig 6

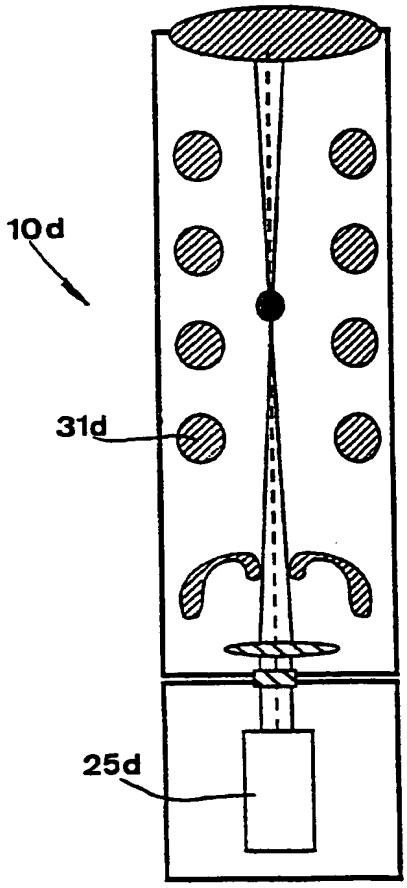

Fig 7

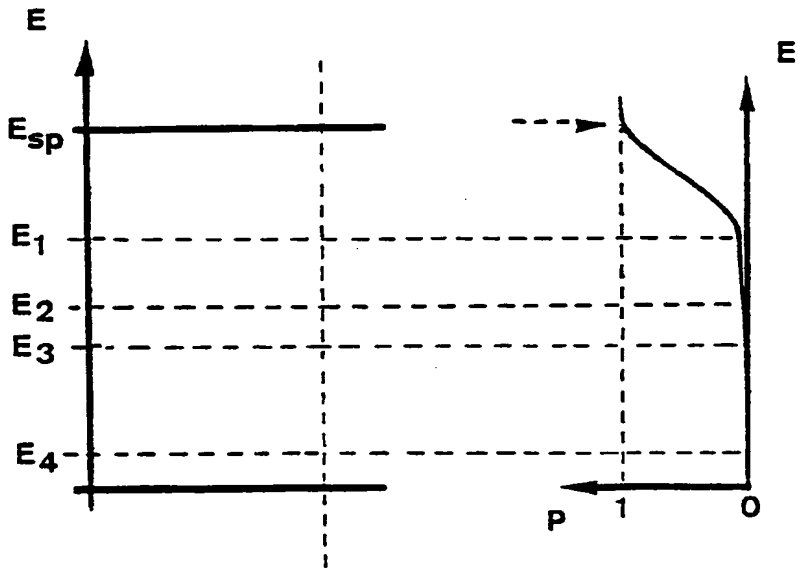

Fig 8

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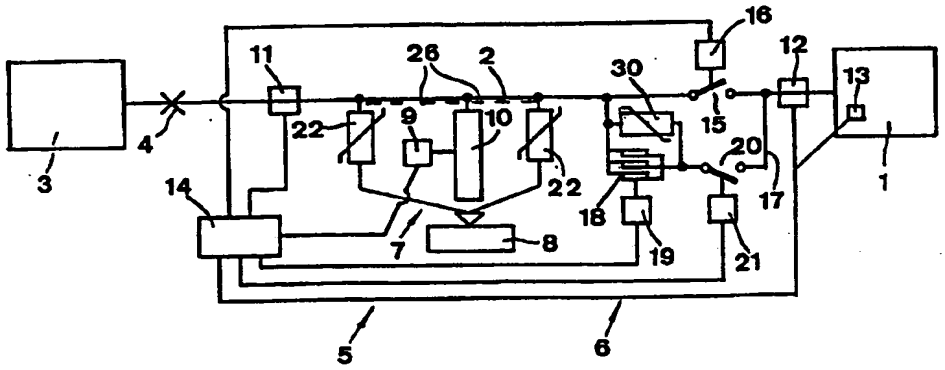

(57) Abstract

This invention is related to a device and a method in an electric power plant for protection of an object (1) against over-currents from a network (3) or another equipment included in the high voltage plant, the device comprising a switching device (4) in a line (2) between the object and the network/equipment. The line (2) between the object and the network/equipment is connected to an arrangement (5) reducing over-currents towards the object (1), said arrangement (5) being actuatable for over-current reduction with the assistance of an over-current condition detecting arrangement (11-13) within a time period substantially less than the break-time of the switching device (4). The over-current reducing arrangement (5) comprises a switch means (10) with an electrode gap, which may be imparted electrical conductivity for over-current diversion.

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INTERNATIONAL SEARCH REPORT

International application No.
PCT/SE 97/02130

A. CLASSIFICATION OF SUBJECT MATTER

IPC6: H02H 9/02, H01T 2/00
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC6: H02H, H01H, H01T

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

SE,DK,FI,NO classes as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

WPI

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 3418530 A (W.H. CHEEVER), 24 December 1968 (24.12.68), column 1, line 45 - line 72; column 2, line 1 - line 15; column 2, line 65 - line 71, figures 1,2	1-3,6,7,14, 29
Y	--	4,5,8-13
Y	Patent Abstracts of Japan, abstract of JP 81-67360 A (TOSHIBA CORP), 31 October 1996 (31.10.96), see the whole document, the figure	4,10-12
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[X] Further documents are listed in the continuation of Box C. [X] See patent family annex.

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Date of the actual completion of the international search	Date of mailing of the international search report
17 June 1998	25.06.98
Name and mailing address of the ISA/ Swedish Patent Offic Box 5055, S-102 42 STOCKHOLM Facsimile No. +46 8 666 02 86	Authorized officer Hans Bagge af Berga Telephone No. +46 8 782 25 00

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INTERNATIONAL SEARCH REPORT

International application No.
PCT/SE 97/02130

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 5153460 A1 (L.J. BOVINO ET AL.), 6 October 1992 (06.10.92), column 1, line 12 - line 14, figures 1, 2, abstract	1-3,5,8-9, 13,15-18, 25-28,30-33
A		6,7
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Y	US 4184186 A (P. BARKAN), 15 January 1980 (15.01.80), column 1, line 60 - line 62; column 2, line 16 - line 29; column 2, line 44 - line 51, column 4 - column 6; column 7, line 55 - line 61; figures 1-2	1-3,15-18, 25-28,30-33
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A	US 4134146 A (E.W. STETSON), 9 January 1979 (09.01.79), column 1, line 1 - line 14	14
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INTERNATIONAL SEARCH REPORT

Information on patent family members

09/06/98

International application No.
PCT/SE 97/02130

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 3418530 A	24/12/68	NONE	
US 5153460 A1	06/10/92	NONE	
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US 4134146 A	09/01/79	CA 1121443 A	06/04/82